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Road Sector Development Issues In The Asian And Pacific Region

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Abstract

The demand for road transport in the countries of the Asian and Pacific region has increased at a greater rate than that of economic growth. After two decades of robust growth road infrastructure is reaching capacity in many corridors. Over the decade to 2010 it is estimated that US$700 billion will be required for new or expanded road networks in the region. Government budgets are already stretched with competing demands from other sectors and are unlikely to be able to provide sufficient resources to meet road sector requirements. Official development assistance can only provide a very small proportion of the overall resources required. As a consequence additional resources will need to be sourced from the private sector and other non-traditional sources, and user charges increased. The establishment of a road fund should be examined as a possible means of raising resources from road users. Another important issue concerns the need to introduce institutional reforms in public sector road management organizations to induce greater competition, efficiency and accountability. The introduction of commercial business practices and the involvement of road users in the decision making process requires institutionalizing if road organizations are to be operated in line with the market. Road safety is a major issue in all countries and there is an urgent need to tackle the excessive accident rates and reduce the carnage currently observed on the region's road networks.

A. Background

The Asia Pacific region has been the leading region in terms of economic growth for the past 3 decades. Despite the recent set backs associated with the Asian currency crisis, the region is still expected to maintain its world lead in economic growth terms, and the impact of the crisis is expected to pass after a period of consolidation of about 2 to 3 years. The region is expected to have learnt from the overconfidence prevalent prior to the crisis and the individual economies are anticipated to emerge stronger as a result. With the two largest economies in the region, the People's Republic of China and India less affected by the crisis, and other economies taking the necessary actions to address required reforms, the overall growth expected for the region is forecast to be in the 3 to 4 per cent range in 1999 and possibly higher in 2000 and beyond. These rates of growth, while significantly lower than those experienced in the past, are very respectable by world standards and owing to a combination of macroeconomic reforms and due diligence measures, growth is likely to be more sustainable over the longer term.

The high rates of economic growth attained in the past have resulted in very large increases in personal wealth in real terms in most of the developing countries in the region. This, in turn, has contributed to substantial increases in the demand for mobility for both commercial and personal reasons. The combined impact has led to large increases in vehicle ownership with the result that there have been very substantial increases in the growth of national vehicle fleets. In many high performance economies the magnitude of the vehicle fleet has doubled in less than 5 years. Despite the phenomenal increases in most of the region, vehicle ownership remains low when compared to the more developed countries such as Japan and Australia. It is to be expected, therefore, that the demand for new vehicles and personal mobility will continue to increase over most of the region as economies continue to expand and incomes increase. The demand within a country is by no means even. As urbanization continues

to increase at a fast pace in most countries of the region, the demand for travel is increasingly focused upon the cities in the region and many, if not all, of the regions major cities are characterized by their gridlocked traffic congestion and high concentrations of air pollution.

The demand for roads and their use is expected to continue to increase at a high rate over the next decade. The demand for mobility will not only be in the urban areas but also extend to travel between the smaller towns and rural communities as urban and rural economies continue to expand and become intrinsically interlinked and more dependent upon one another. Indeed the increasing impact of globalization will also mean that national economies will become dependent upon one another to a greater extent, and this will result in higher demand for better international links to support regional and sub-regional trade and other development opportunities.

The development of road infrastructure is of critical importance for countries to regain and sustain high economic growth, improve the social living standards of their people, and remove the bottlenecks to international commerce and investment. Throughout the region political leaders and economic policy makers recognize that the lack of adequate road networks has become major political, social and economic issue that must be tackled quickly. The current financial crisis and resultant economic slowdown provides a useful breathing space to eliminate existing bottlenecks. However, this respite will not last for long, for as strong economic growth resumes the demand for additional road capacity will continue its urgency once again.

B. Resource Requirements

Over the period to the year 2010 the investment requirements in the transport sector in the region is expected to surpass $ 1 trillion. The road sub-sector is expected to require the bulk of the investment with demand probably exceeding $700 billion. Taking into account the total investments required in each country, and particularly the large requirements to maintain and extend social infrastructure as well as tackle poverty and environmental issues, Government budgets will be hard pressed to allocate additional resources for road development. The demand for investment in the road sector is well in excess of the capacity of public sector budgets in the majority, if not all countries. Therefore, if additional road development is to be provided to minimize the adverse impact attributable to a lack of capacity and accessibility on economic and social development, there will be a need to seek financial support from alternative sources. The primary alternative sources are a combination of investment by the private sector as well as from an increase in user charges.

A considerable amount has been written in recent years over the requirements to attract private capital for infrastructure development. Such preconditions include a sound macroeconomic environment, a stable and transparent legal framework and regulatory system, a policy environment that promotes competition, and availability of long-term capital.

C. Private Sector Participation

Up to the present time most of the emphasis in the roads sector with respect to attracting private sector capital has revolved around the Build-Operate-Transfer (BOT) system and its variants. At the present time there are approximately 75 major tolled highway projects involving private sector finance either operating or under active development in Asia. Of these half are in cities, and most are located in the capital city. As noted above this concentration is not surprising for it is where the major traffic demand is located and it is the tolls on this traffic which will generate the financial revenues necessary for private sector involvement. The remainder of the investments are in the highly trafficked inter-urban corridors which most often are those radiating from the capital city.

Within the roads sector Malaysia has had the most notable success in terms of the number of completed BOT projects, as well as the number under construction and pre-construction. In the early years of private sector involvement Hong Kong, China was the original pacesetter with several very successful tunnel (and transit) projects completed. Other countries in the region that have successfully implemented BOT projects include Thailand, Indonesia, Philippines and the People's Republic of China. A recent survey of BOT expressways indicates that 24 projects are operational and an additional 22 projects are under construction. More than 50 additional projects are in various stages of planning and formulation. Despite the considerable assessed potential for private sector investment relatively few countries have effectively implemented such projects, and the number of projects overall has been well below anticipated levels. In comparison with 5 years ago it is clear that progress in implementation is happening but it is occurring much more slowly than originally expected. While some projects have been canceled many more have been delayed. Because of the huge size of many of these projects they have a significant impact on traffic conditions, and conversely when they are not implemented, there is a major adverse impact upon congestion and levels of accessibility as well as the local economy as a whole. Despite considerable efforts by many senior government officials, politicians and private sector entrepreneurs the implementation of BOT projects remains highly problematic. The success of the completed projects is difficult to assess as no before and after studies are known to exist. Perhaps impact

assessments will come to light in due course after a period of operation. Success evidently reflects the effectiveness of government in attracting the private sector and in devising and applying BOT procedures. Where this has been well developed and policy development has been pragmatic, success is much more likely. Where it is less well developed problems are common, and in the worst cases, often serious.

Two years ago a Bank review of experience in BOT in the road sector noted the following:

that private sector funding had been sought for a variety of road sector projects in a variety of countries across the region

that there is no single, generally applicable model concession agreement for the involvement of the private sector

that the different issues that need to be resolved before a private-funded project can proceed, such as engineering issues, revenue issues, institutional and legal issues and funding issues, have been addressed in many different ways;

that public sector support, in one of many forms, is usually required to complement private sector funding.

Perhaps not unsurprisingly the conclusions of the review indicated that private sector financing of roads depends essentially on revenues covering sufficient project costs to repay debt and contribute returns to the project sponsors. Road sector projects such as expressways, bridges and tunnels range widely in scope from very large mega projects to modest infrastructure such as a small bridge offering time and distance savings. There are no general principals on the amount of debt coverage which on at least one project, has been 100 per cent. In addition there are no rules on the length of the concession period or the minimum rate of return required to gain the cooperation of the private sector. The conditions pertaining to projects were specific to the individual project and depended upon the circumstances prevailing in the country at the time of contract award and the financial standing of the project sponsors.

Projects that have been successful have invariably demonstrated the following characteristics: they had revenue streams of reasonable certainty; the projects were well planned and specified, and were located in stable and fast growing economies with sound macro economic management. With the comparatively high economic growth generally anticipated in the region well planned projects integrated into the road network should be bankable providing the risks are apportioned to those best able to mitigate them and financial returns are reasonable and realistic.

The BOT mechanism generally applies to new construction. While this modality is the most common in Asia there are other variations for which private sector funding can be sought. These include: (i) new construction, management and maintenance an existing transport corridor; (ii) no new construction but management, maintenance and rehabilitation of an existing road corridor, (iii) sale or lease of existing infrastructure built by the public sector, to the private sector to operate as a concession; and, (iv) sale of equity in a tolled facility to raise capital for further investment of the network. The latter proposals have been used by several highway authorities in PRC to raise capital for further extensions to the expressway network.

To date there has been little innovation in the BOT market in Asia in terms of procurement, types of contracts or types of projects. Most Asian projects are BOT projects where a major expressway is to be constructed and initially operated for a period of about 25 to 30 years with the revenue stream being secured by tolling traffic. The main variant has been mechanisms to avoid risk, through government guarantees either explicit or implicit. In other regions there are a range of variants which may have application in Asia. Such possibilities include:

the Design Build Finance and Operate (DBFO) system which is used in the UK and applies to a wide range of new construction combined with management and maintenance of existing roads: it can have performance criteria incorporated in the contracts relating to traffic accidents, extent of lane closures as well as traffic flows.

In South America, the maintenance and/or the upgrading of existing roads (as opposed to new roads) have been let as concessions with the costs recouped through tolls; and staged investment has been required as traffic flows trigger the need for additional capacity (rather than provision of full capacity at the outset).

In the Asia Pacific region there is the need to increase innovativeness in designing and implementing BOT projects. This particularly concerns the improvement in planning and the identification and selection of potential individual projects considered to be suitable for private sector participation. For every individual project there can conceivably be a different type of project or concession agreement formulated. As noted previously the demand for projects is high but the number of projects actually implemented remains well below anticipated levels. There is, therefore, an urgent need for road agencies to examine why fewer projects are being implemented by the private sector and identify possible remedial courses of action.

One of the inherent problems associated with the participation of the private sector in the road sector concerns the planning process. In several countries it is commonly perceived by the public sector that it does not need to undertake detailed project planning

as this can be left to the private sector to finalize. The transaction costs associated with preparing feasibility studies, including environmental and social assessments, can be enormous and are high risk given that there is no guarantee that the project proposal will be accepted or that it will be financially attractive. In some countries unsolicited bids are also permitted on the basis that new and original ideas might be forthcoming and also that transaction costs by the public sector can be minimized. Unsolicited bids have a role to play but more often than not they are the cause of significant problems. Firstly the road agency does not always possess sufficient experience to understand the technical basis for the project and a lengthy period of time is required for the agency to undertake its own internal review. With limited budgets, inadequate data and transport planning models, and few staff with the required skills, internal reviews by government are frequently inordinately lengthy. Secondly, unsolicited proposals have not always been in line with existing plans and programs for the sector. Given the relatively large investment requirements for most projects, the acceptance of a proposal can have a profound impact upon the sector as a whole, which may be detrimental to the long-term development of the network. Further it has been noted that several unsolicited bids have resulted in projects being implemented that are not necessarily in the public interest either from the scope of the project or from the conditions of contract. Overall there is a priority need for road agencies to be proactive in developing projects for participation by the private sector. This will ensure that: (i) the projects are in the national interest; (ii) that projects form an important contribution to the development of the road network; (iii) road agencies are able to properly specify the project requirements; and (iv) that concessions can be negotiated by the Government from a position of strength given that costs, traffic levels and the impact on varying tolls on the level of demand are known estimates, and the environmental and social impacts have been explored. It is very important for road agencies to take the lead in project planning, as it will result in better projects being tendered for private sector participation. It is thus important that road agencies have adequate budgets and resources to undertake the up-front feasibility studies including environmental and social analyses, and also complete preliminary engineering designs. While the required resources will be considerable they are small in terms of total resource needs of the sector and will reap returns in better prepared projects with a greater degree of acceptability to the private sector and capital markets.

The number of projects, which are able to fully repay total costs from a direct revenue stream, is likely to be small in number. If this were not the case the private sector would be queuing to construct and operate a large number of projects in every country. Only highly trafficked roads can be tolled and, therefore, only a small proportion of the network is likely to consist of toll roads and such roads are unlikely to exceed 5 per cent of the major national road network. Tolls are part of a useful strategy but they are only likely to cover a small part of the resource requirement problem. In reality the majority of road projects will not be able to repay their costs based upon reasonable toll levels. The private sector will only enter into agreements that demonstrate a reasonable certainty of return, even if that return has little direct applicability to the actual project. For all projects the public and private sectors need to work together in a very close partnership for the venture to be a success. The public sector needs to provide assurance to the private sector entity that it fully supports the project proposal to demonstrate that both parties are strongly committed to the project. This will generate greater confidence in the proposal and will gather stronger support from potential financial participants. For road sector projects there also needs to be close collaboration between the public and private sectors. Since the public sector establishes the policy framework its involvement and support of projects is crucial to the success of individual projects. For instance projects in the road sector generally require substantial land areas and it is only the public sector that can make land available. In urban areas where the majority of BOT expressways are located the land costs frequently amount to half the total project costs. For projects to maximize their utilization, accessibility with the adjacent road network will need to be improved and this is likely to require complementary investment from the public sector. Another feature is that few projects can truly be implemented by the private sector without some financial support from the public sector. The common perception that all road projects are "gold mines" able to generate large quantities of funding, needs to be redressed. If road sector agencies want to maximize the level of financial support from private sector sources it is likely that financial support would need to be provided for the majority of projects if cost effective deals are to be closed. There are many examples where bidding documents have requested bidders to identify the amount of financial support or equity investment required from the public sector to make the project bankable and implementable.

D. User Charges

In addition to securing investment resources from the private sector there is also the important need to review user charges. In Asia those countries with well developed networks and large vehicle fleets tend to be characterized by the situation where the revenues from the sector are significantly larger than expenditures. However, this does not imply a satisfactory situation since maintenance expenditures are often below

requirement levels and investment is frequently less than optimum. Road agencies together with their respective national planning and finance agencies need to periodically examine user charges to see that they are appropriate for conditions pertaining on the network (as well as between modes). In this respect it should be noted that not all charges might be reasonably assumed to accrue for road development. For those taxes that occur across the economy, such as value added taxes or sales taxes, the amount levied should go towards the general expenditures of the economy. However, it might be possible to add tax and fee components specifically for road sector development and it is these possibilities that need to be examined to generate additional resources for roads and road development. The examination of road user charges needs to focus upon those charges that would vary with road use rather than fixed charges. Variable charges are considered preferable on grounds of equity not only because they are contributed to by actual use of the network, but they also have a closer approximation to the pricing system in a market economy. In economic terms they are more efficient in resource allocation.

During the next decade road authorities can be expected to be more preoccupied with congestion and pollution pricing as these issues increase in economic and social importance and rise to the top of political agendas. While surcharges on fuel are very cheap to collect and are able to raise considerable revenue, other forms of pricing are also likely to be attractive. The concept of electronic pricing has been discussed for several years and a large-scale experiment was conducted in Hong Kong, China in the early 1980s that proved such possibilities are technically workable. Most recently Singapore has introduced electronic road pricing using smart card technology on part of its congested network and it will be most interesting to see the impact after a period of operation. New Zealand is experimenting with satellite based GPS systems and anticipates that such a system will be implemented on its trucking fleet within a few years. It is expected that the system will be extended to the rest of the vehicle fleet when the demand for the technology is such that the costs will reduce to acceptable levels. If such systems can be demonstrated to work, and overcome the hesitancy associated with loss of personal freedoms, they are likely to become very attractive for road agencies, particularly those having to cope with high levels of congestion. Electronic pricing will enable road agencies to manage their networks using market principles by adjusting price according to demand and supply relationships. In addition the traditional sources of revenue such as vehicle registration fees, driver licenses, road user charges, and a portion of fuel taxes need to be reviewed from time to time to ascertain whether an increase is warranted.

E. Road Funds

In some parts of the world including Japan, Korea, New Zealand and the USA road funds have been established to provide resources to maintain and extend the road network. The basic concept of a dedicated fund is to guarantee that sufficient resources will be available to undertake the anticipated work and thus ensure sustainability of the infrastructure over the long-term. Since the value of a country's road network is worth between one-half and 3 times the annual GDP, and the annual costs of road transport and road management are commonly in the range of 3 to 7 per cent of its Gross Domestic Product, preservation of the investment should be given high priority. The establishment of a road fund is usually based on the premise that the fund should only consist of road user charges and exclude resources from any other source. It is important to consider the funds as charges for road use and not as a Government tax. In this way there is no controversy over their commitment for investment in the road network. The objectives of the fund should be clearly stated so that it is easy to demonstrate whether it is achieving its intended purpose. It should also be managed transparently, ideally by a team led from outside the sector, and including representatives from a diverse background of users as well as Government representatives. Accountability must be paramount and investment criteria for allocating resources well understood. The establishment of dedicated road funds enables resources to be committed without recourse to annual commitments by legislators which are frequently subject to the vagaries of political change. The major benefit of creating a dedicated road fund is that it is the mechanism that is most likely to generate the level of resources required to properly manage a road network.

It can safely be said that road agencies need to explore all options. The creation of a dedicated road fund could provide the bulk of resources required to sustain an efficient road network, but alternative sources of funding and participation by the private sector can make very important contributions, particularly on high volume routes where tolls revenues can be used to repay investment costs.

F. Institutional Reform

Closely linked to the question of financing is the issue of the institutional effectiveness of the public sector. For most of the countries in the region development and management of the roads sector is widely considered to be the preserve and obligation of the public sector. However, increasingly it is recognized that while the public sector needs to carry out its obligations both efficiently and effectively, it needs to operate more like the private sector. It needs to be

operated and managed on commercial lines. In many countries the public sector has been used extensively as a tool of public employment policy and bureaucracies have been filled with large numbers of staff with little regard to actual work needs or practices. For instance within the past decade it was common to find that high proportions of road maintenance budgets were allocated for staff salaries and administrative services leaving minimal allocations to be spent on physical maintenance activities. In some countries maintenance funds are used primarily for other purposes such as improvement or upgrading as allocations for these purposes are often substantially below requirements adding considerably to a backlog of future required investment.

One of the basic problems with road agency operations in many of the Asia Pacific countries is the almost total separation between the road sector providers and road users. Commonly road agencies plan road networks, receive and spend budget resources without any recourse to users. Road users have no sense of ownership even though they are paying both directly and indirectly through the tax system for the development, maintenance and management of the road network. Road agencies have the responsibility to implement the political decisions of Government and one of their prime concerns is to ensure that funds are disbursed as appropriated, and not whether they are consistent with the priorities of road users. In a commercially oriented organization high priority is accorded to customer satisfaction, even in a public sector organization. There is the need to create greater awareness in road agencies as to the role and attitude that public sector institutions and employees should have and a better understanding of the service they are providing on behalf of the population as a whole. At the present time there is generally little public awareness or accountability in the present institutional framework as road agency personnel are largely not answerable for their actions or inaction's to the public. This long established situation gives rise to a system where everyone is able to blame everyone else for the resulting problems. To enhance the efficiency and effectiveness of road sector operations there is an increasing requirement for sector agencies to become much more aware of their responsibilities and to integrate the demands of road users into their regular business practices.

There is also the need to review the business practices of road agencies to ensure that the efficiencies of the private sector are also being approached, if not attained, in the public sector. In several countries the Government has taken the decision to outsource those activities that can more appropriately and efficiently be undertaken by private entities. Construction is commonly undertaken through contracts awarded on a competitive basis and a number of countries now also outsource road maintenance to private contractors. Outsourcing and other commercial practices can be applied widely across the sector including the planning, design, construction and maintenance functions including operation of plant and equipment workshops. While few countries such as Malaysia have actually decided to outsource a high proportion of its operations, a number of others including the Philippines are studying the possibility of extending the amount of work activities that could be undertaken by the private sector. In New Zealand and parts of Australia commercialization, including corporatization and privatization, have been implemented on a wide scale. Almost all aspects that can be undertaken by the private sector have been either contracted out or sold: remaining entities have either been corporatized or have remained as state entities with the major difference that they have been restructured to operate using commercial business practices. Government departments have been reduced in size substantially and have been refocused to concentrate on planning and managing the sector. The changes have been drastic but have resulted in large-scale efficiencies. Following restructuring of the public sector the remaining components of the agencies that remain in Government's hands are operated similar to businesses in the private sector: their operations are based on well defined corporate plans which identify clear goals and objectives. Performance criteria are an integral part of the plan that is regularly monitored to establish feedback and determine whether performance is being attained and the goals and objectives met. The planning process is focused upon achieving outcomes rather than inputs and outputs. This is because outcomes are the end result of a series of inputs and outputs and it is the overall results that are important to policy makers. They are interested in ascertaining whether the intended policies are being achieved and are less interested in how they are being achieved. To maintain efficiency Government agencies should have to compete with private sector companies to obtain contracts from Government rather than automatically be awarded all contracts in the sector. The institutional changes, which were initiated in New Zealand and have subsequently been adopted in Australia and other countries have resulted in widespread efficiency gains, and have had a profound impact upon the public perception of the public sector. It is perhaps not possible to say whether similar forms of institutional restructuring and introduction of commercial practices will be fully endorsable in the Asia Pacific context and it will up to the individual country's political and social culture to determine whether and to what extent restructuring can be undertaken. Nevertheless road agencies need to examine the spectrum of possible efficiency impacts to determine how they, and the country as a whole, might benefit from them.

G. Road Safety

Road safety is of major concern throughout the Asian and Pacific region. Road accidents are already a major cause of death and are expected to rise dramatically if actions are not taken to address the primary causes. While the region as a whole is generally in the early stages of motorization vehicle ownership is increasing steeply in many countries and vehicle fleets are doubling every 5 to 7 years. In many countries a high proportion of vehicles are 2-wheeled motorcycles and non-motorized vehicles and many users of the road environment are pedestrians. These facts coupled with the relatively young age of the population and the relative lack of awareness and attention given to tackling road safety are factors that contribute to the road safety problem. Official statistics indicate that at the present time approximately 250,000 road deaths occur each year and a further 3 million people are severely injured or crippled due to road accidents. If actions are not taken to address this issue the number of deaths is expected to rise to at least 500,000 a year within the next decade. Of particular concern is the severity of the road accident problem that is reflected in the high accident rates that are occurring in many developing countries. The number of deaths per 10,000 vehicles is significantly above levels currently attained in Australia, UK or Japan. Many countries in the region have fatality rates between 20 and 30 times those of Australia, and even those at the lower end of the scale record an 8 to 10 times increase. On the evidence available there is substantial cause for alarm and considerable room for improvement. The cost of road accidents imposes a considerable burden on the economies of the region and conservative estimates indicate that at least $20 billion a year is lost through road accidents.

H. Conclusions

In conclusion the road sector in the Asia Pacific region is at another turning point. Over the next decade economic development is expected to continue at a slower pace than in the past 20 years, but is anticipated to attain a level which will continue to increase the pressure on existing road infrastructure. In most countries substantial additional road capacity will be needed to sustain economic and social development and this will require considerable financial resources generally in excess of current budgetary allocations. Estimates suggest about $1 trillion will be required for the transport sector as a whole with the demand from the road sub-sector exceeding $700 billion. Governments will need to provide the bulk of the capital requirements although a significant portion should be possible to source from the private sector. Since the majority of the works expected to be attractive for private sector participation are likely to be large projects for which toll revenues will be available to repay costs, they will inevitably be the largest and most important components of road sector development plans. The private sector cannot operate in a policy vacuum and can only respond to public sector policies and initiatives. Therefore, the private sector cannot participate in the road sector without support from the public sector, as it is the latter that determines road sector policy and strategy. As a result it is critical that the public sector creates the necessary framework for private sector participation which needs to be viewed as a partnership. In addition it is necessary for agencies to examine road user charges to see whether there is scope for increasing revenues for road sector development with a particular focus on charges that vary with road use. In this context it is important to distinguish road user charges from taxes. In some countries there may be possibilities for establishing dedicated road funds which are a reliable means of allocating resources for road development and management and the most likely means for providing sufficient funds to sustain road networks. In the future more emphasis will be placed on the efficiency of the public sector which needs to be managed using similar commercial criteria and techniques as private sector entities. Outsourcing of operations that can be competently undertaken by private companies need to be assessed and either corporatized, privatized or contracted out. During the next decade road agencies will need to place greater emphasis on management and management techniques for in their new role the efficiency and effectiveness of their operations will place high priority on using modern management skills accompanied by advances in technological innovations. Last but not least is the need to tackle deteriorating road safety. The number of fatalities and injuries sustained on the region's road networks has reached very high levels, which is placing a large economic and social cost on individual economies.

Transport of dangerous goods through road tunnels

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The Problem

With increasing motorization, road networks have been extended world-wide with several impacts on societies, economies and industries. Traffic volume has increased tremendously during the last fifty years and will continue to grow for the foreseeable future. In extending the road network, increasing numbers of tunnels are necessary not only in mountainous areas but also in and around built-up areas in order to reduce noise and the effects of air pollution.

Among the goods transported by road, some have a special attribute: they are hazardous or dangerous. This means they are flammable, explosive, radioactive, poisonous or present some specific danger for man and environment. Special risks occur if these goods are transported through tunnels. International regulations, such as the United Nations Recommendations on the Transport of Dangerous Goods ("Orange Book") or the European Agreement on the Transport of Dangerous Goods by Road (ADR), classify goods for road transport conditions in general. However, there are no existing international rules or recommendations for the transport of dangerous goods through tunnels for many reasons, including:

1. Tunnels are very different in construction, length, equipment, traffic conditions, etc.
2. There are different detour routes.
3. There are different policies in different countries.
4. There are sometimes very different local circumstances.

On the one hand, the low transport costs and journey times associated with tunnels lead to increasing transport volumes and, concurrently, greater demand to allow dangerous goods through these tunnels. On the other hand, society is increasingly sensitive to safety issues, resulting in a trend toward restricting dangerous goods through tunnels. One goal of the project is to address these competing demands.

The following factors can be used to describe the structure of the problem :

- growing average tunnel length;
- growing traffic volume in general;
- increasing need for longer distance in transporting of dangerous goods;
- no general recommendations on the need for, nor uniform procedure for, calculating the risk of dangerous goods transport through road tunnels in a quantitative manner;
- no international harmonized recommendations for decisions on how to handle the transport of dangerous goods through tunnels.

Some countries are very much aware of the need to find an international solution. However, there are still other countries that do not fully recognize this growing and potentially serious problem for society.

The project

Due to an urgent need for scientific treatment of this problem, the two international bodies with extensive experience in the road transport field — the OECD Road Transport and Intermodal Linkage Research Programme (RTR) and the World Road Association (PIARC) — have joined forces in a common research project entitled "Transport of Dangerous Goods through Road Tunnels". Four tasks have been defined:

- Task 1: Review current national and international regulations;
- Task 2: Refine and/or develop methodologies relating to risk assessment and the decision process;
- Task 3: Identify and prioritize risk reduction measures (including transport and tunnel operation);
- Task 4: Conclusions and recommendations.

From the beginning it was clear that this work would need financial support to collect the necessary data, develop the methods and models and test them in practice with the final users. A research plan that outlined the timing and budget needs was designed and countries were asked to financially support the work. A number of these countries took the opportunity to participate in this internationally coordinated and controlled research project because they believed it would have significant implications on their safety, environment and traffic policies. For an individual country to develop a similar project would cost several times more than their contribution to this international effort.

The Project Structure

Referring to Figure 1, the RTR Steering Committee and the PIARC Committee on Road Tunnels make decisions at the executive level concerning the objectives, initiation, organization, financing and follow-up of the project. They have created an Executive Committee to oversee the financial and policy issues. The Scientific Expert Group prepares the detailed objectives, plans and budget and is responsible for the general advancement and the results of the project. Three sub-groups have been established to deal with the various tasks.

Task 1: Review of current national and international regulations

Task 1 is aimed to answer the question: What is the situation in different countries in this field? Its objectives were to provide an overview of current regulations, evaluate their qualities and the problems they pose, and to draw lessons on needs and requirements for new regulations. This task was divided into two missions. Both missions were carried out by a Norwegian consultant and have been completed. The reports are freely available [6, 7] on the internet: www.oecd.org/dsti/sti/transport/road.

Mission 1: A survey by mail to facilitate the collection and analysis of existing data.

Mission 2: The examination of application (or other) problems on an interview basis for a select number of countries leading to a set of conclusions.

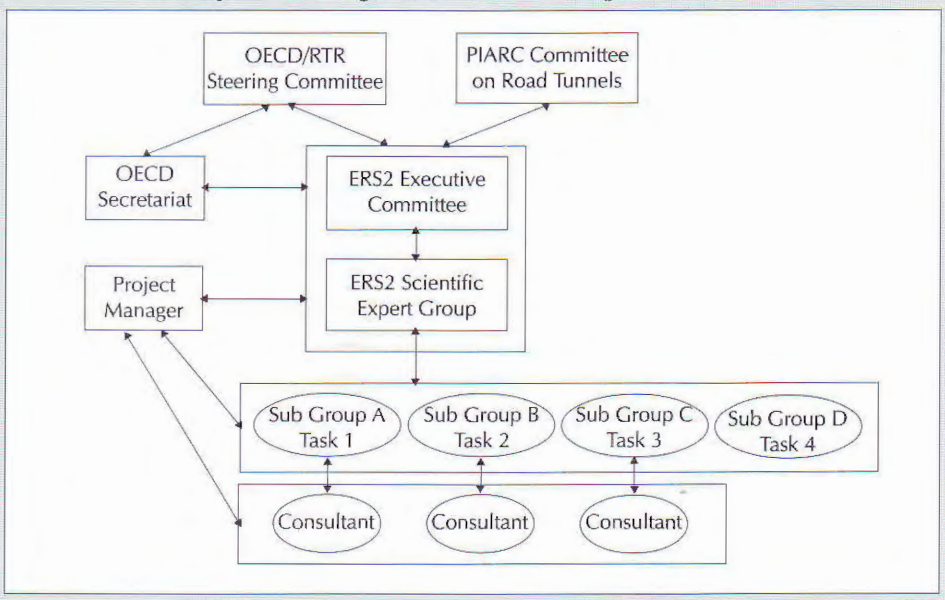
Mission 1: The Survey

Mission 1 of Task 1 consisted of a survey. A questionnaire was submitted to 24 countries in January 1996. 22 countries returned the completed questionnaires. One of the countries does not have any road tunnels, hence the analysis is based on the answers from 21 countries. A technical report and a database covering the information for each reported tunnel are now available.

The main results of the survey are (Figure 2):

- Most countries have no general rules and regulations for the transport of dangerous goods in tunnels, but rules and regulations applying to specific tunnels have been developed in a number of countries.
- In Europe, the ADR or codes based on the ADR are commonly being used for defining the transport of dangerous goods by road. Most US states and Canadian provinces follow codes in compliance

Figure 1: Organisation of the ERS2 Project on Transport of Dangerous Goods Through Road Tunnels



with the UN Orange Book. Australia and Japan have their own codes for defining dangerous goods by road.

- In comparison to tunnel-rich countries such as Norway and Italy, countries and/or regions with few tunnels (the Netherlands and the Belgian region of Flanders, for example) often have more and stricter regulations regarding the transport of dangerous goods in tunnels.
- Two accidents in road tunnels involving dangerous goods were revealed in the questionnaires. (However, the PIARC Road Tunnels Committee members are familiar with others.)

In the majority of countries with road traffic regulations for tunnels, tunnel specific rules are applied. However, only 30% of countries have general rules for the transport of dangerous goods in tunnels. This orientation and the rather complicated mix of systems therefore make international transport very difficult.

As Figure 3 shows, risk assessment is not often used as decision support criteria for restricting the transport of dangerous goods. This so-called general experience is the main practice for restricting the transport of dangerous goods.

Figure 2: General and Specific Rules for Transport of Dangerous Goods Through Road Tunnels

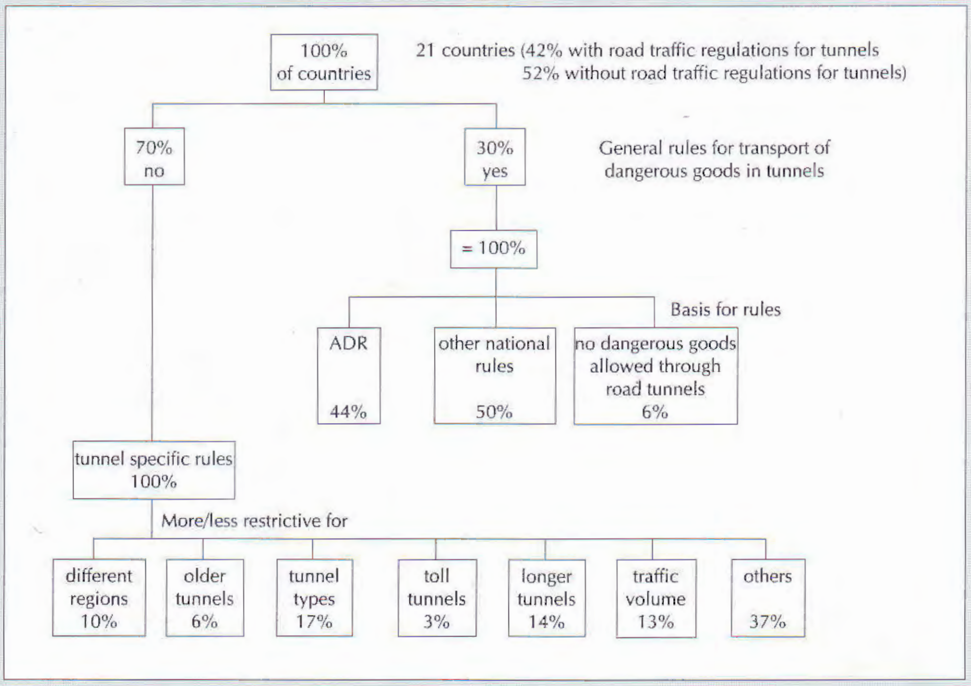
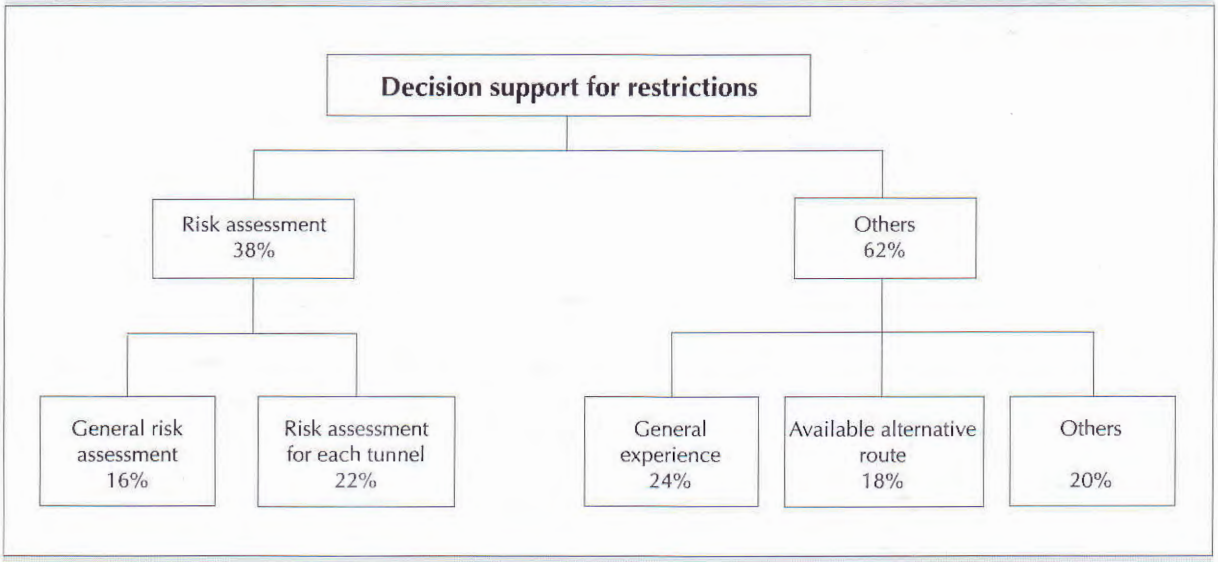
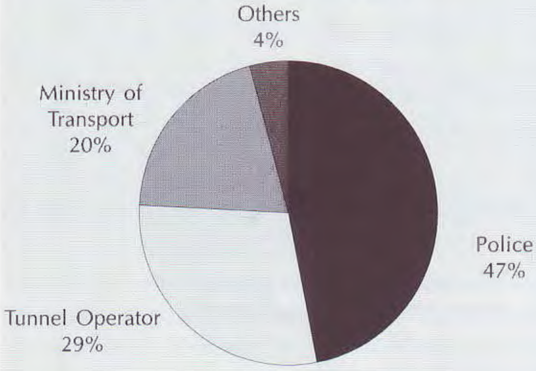


Figure 3: Decision Support for Restricting the Transport of Dangerous Goods Through Tunnels



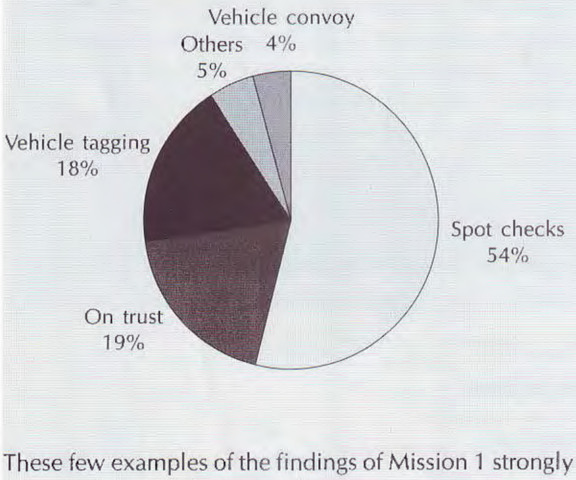
The responsibility for enforcement of rules is also not uniform in the responding countries. The police are responsible in 47% of cases, tunnel operators in 29% and ministries of transport in 20% (Figure 4). Assignment of responsibility for enforcement depends on the type of road going through a tunnel.

Figure 4: Responsible Body for Enforcement of Rules



It is important to have good information on the means of enforcement in order to truly know whether or not a system is working. Figure 5 shows that spot checks are the principle means of enforcement. The responses to the questionnaire also highlight that the exact number of vehicles transporting dangerous goods through tunnels is currently unknown and statistics on the quantity of illegal transport are not available.

Figure 5: Means of Enforcement



These few examples of the findings of Mission 1 strongly support the need for international research such as this project. These findings are also important for both the comparison between countries and as background information for future work in PIARC and OECD.

Mission 2: Detailed information and evaluation

Mission 2 of Task 1 was performed in 1997. From the results of Mission 1, the following countries were chosen for interviews: Austria, France, Germany, Holland, Japan, Norway, Switzerland, United Kingdom and United States (State of California). The results of this interview-based study supplement the questionnaire results of Mission 1.

A great variety of restrictions are imposed on the transport of hazardous materials in road tunnels. These include: inter-vehicle distance, speed limit, hourly/daily limitations, escorting requirements, mandatory notification of cargo, amount and type of substances, requirements for vehicle and tunnel provisions, and others.

There is limited information available on how existing regulations are respected by dangerous goods carriers, though infringements are known to take place at least in tunnels with no permanent control. The level of control and attention from the police or fire brigades is limited to spot checks (or none at all) in most cases. The exceptions are at tunnels crossing borders where permanent controls are performed by customs personnel.

Many of the problems identified in the Mission 2 report could be dealt with by introducing proper and standardized (international) road signs for dangerous goods restrictions and providing information on available diversion routes (by road). In addition, hauliers could be made aware of the various regulations through an extensive distribution of information in official gazettes or newsletters. For foreign hauliers, relevant material should be made available at border crossings or at toll stations.

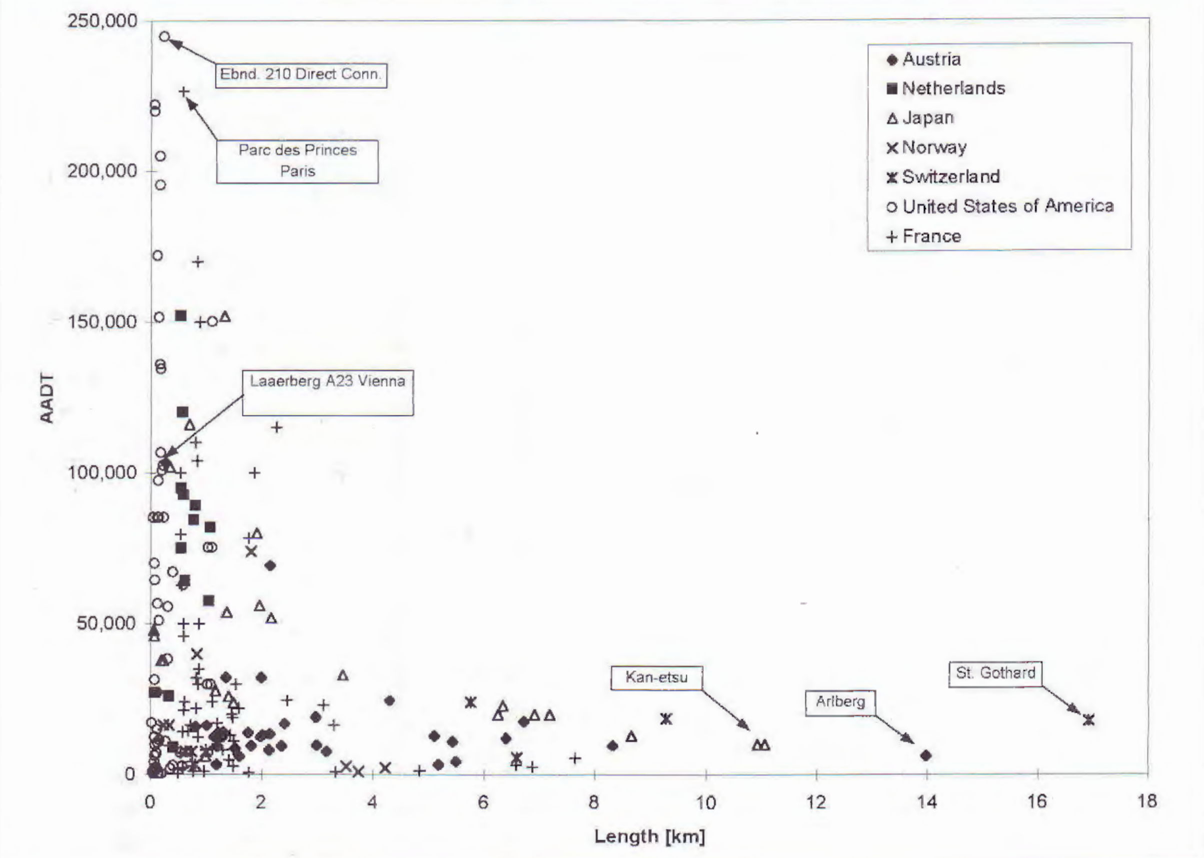
A statistical analysis of tunnels can partially explain some of the seemingly contradictory findings. Figure 6 shows the relationship between traffic volume and length of tunnels in different countries. Very high traffic volumes with 100,000 vehicles per day or more are only found in tunnels shorter than 2.5 km. In tunnels over 4 km the average daily traffic is below 25,000 vehicles per day. However some of the longest tunnels have traffic near 20,000 vehicles per day, which is still heavy.

This can be better understood by distinguishing between urban and rural areas, as tunnels in urban areas normally have high traffic volumes and short lengths. Most of the urban tunnels identified in the study have a length less than 2 kilometers, though the longest is slightly over 3 kilometers.

Task 2: Methodologies relating to risk assessment and the decision process

The objective of Task 2 is to recommend methodologies and propose models for evaluating risks in tunnels, comparing them with alternative routes and proposing decisions using standard formulations.

Figure 6: Traffic Volumes in Different Length Tunnels



Phase I

An inventory and comparison of existing methods to evaluate risks in tunnels were presented at a seminar in Oslo in March 1996 [8]. After the seminar, the Scientific Expert Group structured Task 2 as a Quantitative Risk Assessment (QRA) followed by the use of a Decision Support Model (DSM).

At the same time, it was proposed to develop a grouping system (GS) for loadings of dangerous goods. This system could be used in harmonized tunnel regulations to facilitate decisions ranging from the allowance for all dangerous goods to the allowance for none.

Phase II

As a consequence of the above, the second phase was split into three activities that run in parallel: (a) Quantitative Risk Assessment, (b) Grouping of Dangerous Goods Loadings and (c) Decision Support Method.

(a) Quantitative Risk Assessment

Detailed specifications were prepared for the development of a model and submitted to a peer review group composed of leading institutes and experts in the field of Quantitative Risk Assessment. This review was followed by an international call for tenders, the evaluation of the tenders and the choice of consultants. A consortium of French, British and Canadian consultants is currently developing the model which will be validated using several test cases.

The first step of the work was to choose the dangerous goods and the scenarios involving those dangerous goods which would be examined by the QRA model. The dangerous goods chosen were:

- HGV with dangerous goods,
- LPG in cylinders (50 kg),
- Motor spirit in bulk (30,000 l),
- Ammonium in bulk (20 t),
- LPG in bulk (18 t).

Using the selected dangerous goods, a number of scenarios were chosen for the development of the QRA model. The scenarios were chosen so as to get a probability consequence product that is not negligible in the tunnel or in the open. Consequently, in the majority of scenarios chosen it is assumed that the whole quantity of dangerous goods transported are involved in the scenario. The following scenarios were chosen:

1. HGV fire (20 MW)
2. HGV fire (100 MW)
3. Boiling Liquid Expanding Vapour Explosion (BLEVE) of LPG transported in a 50 kg cylinder
4. Pool fire of motor spirit following a release through a 80 cm^2 breach of a bulk compartmented (thin surface easy to puncture) or non-compartmented (more robust) tanker.

5. Vapour Cloud Explosion (VCE) of motor spirit following a release through a 80 cm^2 breach of a bulk tanker.
6. Toxic release of ammonium following a 50 mm diameter breach of a bulk tanker.
7. Boiling Liquid Expanding Vapour Explosion (BLEVE) of LPG transported in bulk.
8. Vapour Cloud Explosion (VCE) of LPG following a 50 mm diameter breach of a bulk tanker.
9. Torch fire of LPG following a 50 mm diameter breach of a bulk tanker.

For some DG, there is only one associated scenario. For LPG, there are 4 associated scenarios. Nevertheless, even in the case of a DG with only one associated scenario, numerous calculations will be carried out by the model and a great many points will form the Frequency / Number of Casualties curve.

This is because the spreadsheet will take into account:

- different global traffic (peak hours, normal, quiet),
- different DG traffic (peak hours, normal, quiet),
- different open route sections with varying surrounding population densities,
- probably different delays for the forbidding of access to the dangerous location,
- probably different delays for the occurrence of the scenario,
- different in-tunnel locations of the scenario occurrence.

The FORTRAN program of the model uses a two dimensional description of the population in the open, taking into account data on population distribution, work day population, the road, the tunnel, methodology, and the environment.

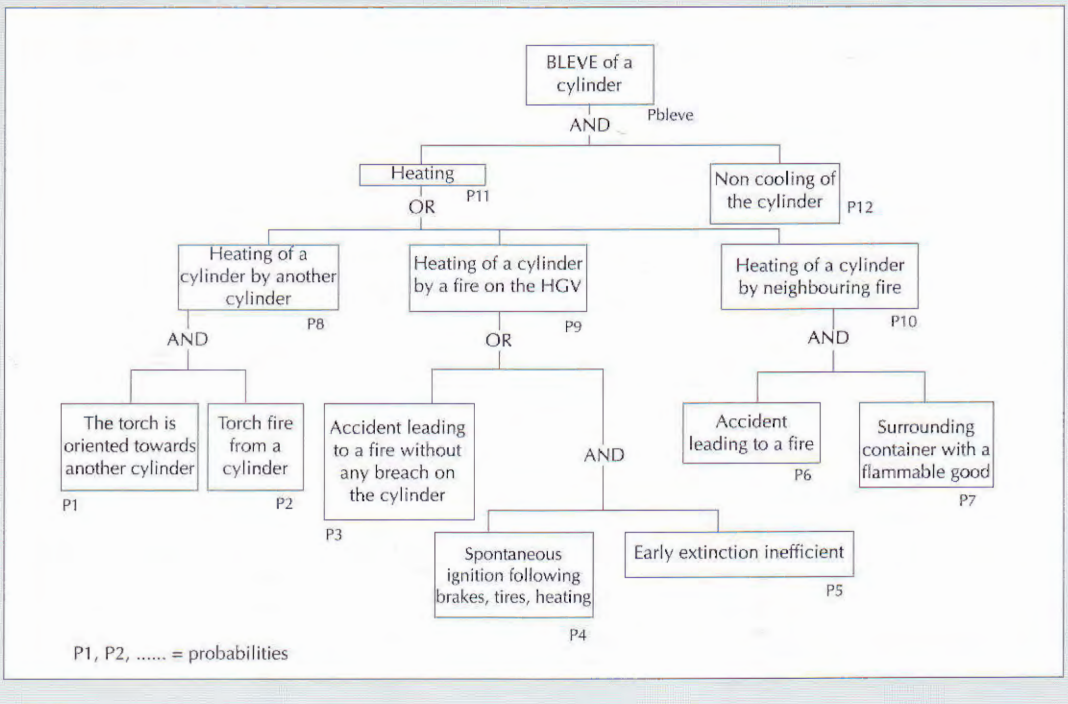
Consequences of the selected scenarios

It is necessary to assess the physical and then the physiological consequences of the scenarios. These consequences will be assessed for "normal sites and conditions", for example, the presence of a refinery along a route section which may trigger scenarios on the road would not be taken into account. In the same manner, specific external conditions of a tunnel would not be dealt with. The exception might be for underwater tunnels for which a roof collapse could be considered.

For practical use, four test cases were chosen which cover a wide range of different characteristics (length, type of traffic, urban, landscape or mountainous area). Figure 7 gives an example of an event tree for the "BLEVE" situation. The model has been available since December 1st 1998 and is now in the validation phase in which the following countries are taking part: Austria, France, Norway, Netherlands, Sweden, Switzerland, United Kingdom, United States

An important part of the development of the QRA model was the estimation of the risk of accidents and incidents involving heavy goods vehicles and especially with vehicles transporting dangerous goods. This work is incorporated within the QRA model "tool box".

Figure 7: Example of an Event Tree for the BLEVE Situation



Groupings of dangerous goods loadings

A first proposal has been drafted to establish 3 to 5 groupings of dangerous goods loadings to be used in standard tunnel regulations. A discussion document is available [9] and has been submitted to most interested international bodies, including those of the United Nations in Geneva in charge of dangerous goods transport.

There are several ways to develop groupings of dangerous loadings for a practical system. An example of a system with five groupings was derived as follows:

- **Grouping A:** All dangerous goods loadings authorized on open roads (by UN or ADR regulations).
- **Grouping B:** All loadings in grouping A except those which may lead to a large explosion.
- **Grouping C:** All loadings in grouping B except those which may lead to a large toxic gas release.
- **Grouping D:** All loadings in grouping C except those which may lead to a large fire.
- **Grouping E:** No dangerous goods loadings exceeding the limited quantities (UN chapter 15, ADR marginal 10 011).

Grouping E could be merged with grouping D, leading to four groupings only, if loadings with minor hazards were deemed acceptable in all road tunnels. However it is probably preferable to keep grouping E so as to have the possibility to ban all loadings for which a special *marking* is required, just as in the open. Table 1 gives an example groupings drawn up by the French authorities in charge of the transport of dangerous goods.

Table 1: Example of Loadings Using Five Groupings

Class	Grouping A	Grouping B	Grouping C	Grouping D	Grouping E
	(All loadings authorized by ADR)	(Grouping A minus risk of large explosion)	(Grouping B minus risk of large toxic gas release)	(Grouping C minus risk of large fire)	(Not more than limited quantity of ADR 10 011)
1	All	ADR 10 011	ADR 10 011	ADR 10 011 (1)	ADR 10 011 (1)
2	All	F, TF, TFC in cylinders only. A, O, T, TC, TO, TOC	F in cylinders only. A, O	A, O	ADR 10 011
3	All	All except No.6 and 7	No. 1-5, 31-34, 61c	No. 1-5, 31-34 in packages	ADR 10 011
4.1	All	All except self-reactive B	All except self-reactive B	PG II, III except self-reactive	ADR 10 011
4.2	All	PG I in packages PG II, III	PG I in packages PG II, III	PG II, III in packages	ADR 10 011
4.3	All	PG I in packages PG II, III	PG I in packages PG II, III	PG II, III in packages	ADR 10 011
5.1	All	PG I in packages PG II, III	PG I in packages PG II, III	PG II, III in packages	ADR 10 011
5.2	All	All except type B	All except type B	ADR 10 011	ADR 10 011
6.1	All	No. 11-90	No. 11-90 PG I in packages No. 11-90 PG II, III	No. 11-90 PG I in packages No. 11-90 PG II, III	ADR 10 011
6.2	All	No. 2, 3, 4	No. 3, 4	No. 3, 4	ADR 10 011
7	All	All	All except UF_6	All except UF_6	ADR 10 011
8	All	All except No.6	PG I in packages PG II, III	PG I in packages PG II, III	ADR 10 011
9	All	All	All	All except No. 4 in bulk	ADR 10 011

1. Other possibility: forbidden
2. PG = Packing Group
3. For classes 3, 4, 5, 6, 8, 9, substances that do not have a letter in the ADR list should be considered as PG I
4. Transport of the limited quantities specified in ADR 10 011 is authorized in all groupings

Consistency with the QRA model development under Task 2 of the Research Project

There are strong links between the development of the QRA model and the definition of groupings of dangerous goods loadings:

- the QRA model must incorporate accident scenarios representative of each of the groupings,
- each loadings group should correspond to the possibility that one or other of the accident scenarios included in the QRA model happens:

The terms of reference for the development of the QRA model require that five accident cases should be studied: heavy fire without dangerous goods; motor spirit transported in bulk; cblorine transported in bulk; LPG transported in bulk and in cylinder. Table 2 shows that these scenarios are quite well representative of the five groupings described in the previous paragraph:

Table 2: Accident Cases Representatives of Each Grouping for the QRA Model

Grouping of loadings	Representative accident cases for QRA
Grouping A	LPG in bulk and in cylinders; chlorine in bulk; motor spirit in bulk
Grouping B	Chlorine in bulk; LPG in cylinders; motor spirit in bulk
Grouping C	Motor spirit in bulk; LPG in cylinders
Grouping D	Heavy fire without dangerous goods
Grouping E	Heavy fire without dangerous goods

The next step is to discuss these proposals inside and outside the Scientific Expert Group in order to achieve decisions on the principles first, and on the definition of groupings of dangerous goods loadings afterwards, and certainly after further work has been undertaken. This will include checking the relevance of the proposed systems in more detail *vis-à-vis* the QRA model being currently developed in the framework of the Research Project.

Decision Support Model

A consultant was charged with the task of reviewing existing decision support models and asked to recommend whether existing models could be adapted for the purposes of this project or if a new model needed to be developed.

Since Decision Support Models are often used in different fields of science no new tools need to be developed. The survey of the models gives an overview of the terminology, the types of Decision Support Models, including the basis decision analysis, multi-attribute decision analysis, cost benefit analysis and other methods. The practical use of decision analysis described with illustrative examples. A number of decision processes were discussed, the next step of the project will be to develop this process for practical use.

Using a QRA, DSM and the different measures analyzed in Task 2, will allow the problem of the transport of dangerous goods through tunnels to be handled in a much more systematic way than it has been done to date.

Phase III

The next steps have not yet been finalized. They should, however, include the validation of the QRA and DSM models developed or studied under Phase II and the finalization of an harmonized system to regulate dangerous goods in tunnels.

Task 3: Risk reduction measures (including transport and tunnel operation)

The objective of Task 3 is to recommend risk reduction measures for tunnels that are well adapted for each specific case, with detailed specifications and an evaluation of the costs and effectiveness *vis-à-vis* the associated risks. Task 3 is organized in three phases.

Phase I

Detailed description and analysis of known measures and evaluation of (dis)advantages.

Phase II

Cost/effectiveness evaluation based on risk analysis adapted for each specific case.

Phase III

Specifications for improved or new measures using advanced telematics or other technology; possibly pre-development or new measures.

The investigation of measures to reduce the risk of transport of dangerous goods through tunnels was based on a literature survey, interviews with several tunnel managers and their ranking of the measures studied. Eleven tunnel operators in France, Italy, UK, Austria and the Netherlands were surveyed and this has to be taken into account for the interpretation of the findings. The study resulted in a ranking of different measures with regard to (i) the reduction of the number of victims (Figure 8 and Table 3) and (ii) the effect on reducing structural damage to the tunnel. This is a basis for discussion and provides a reference list for systematic scientific work when using the QRA model in the future.

Task 4: Conclusion and recommendations

The objectives of Task 4 are to propose a standard international formulation for tunnel regulations concerning dangerous goods, to recommend a general methodology to prepare decisions on authorizing or refusing the transport of dangerous goods, and to recommend appropriate measures to reduce risks. This work is based on the results of the previous tasks.

Figure 8: Ranking of Measures by Their Effects on Reducing the Number of Victims

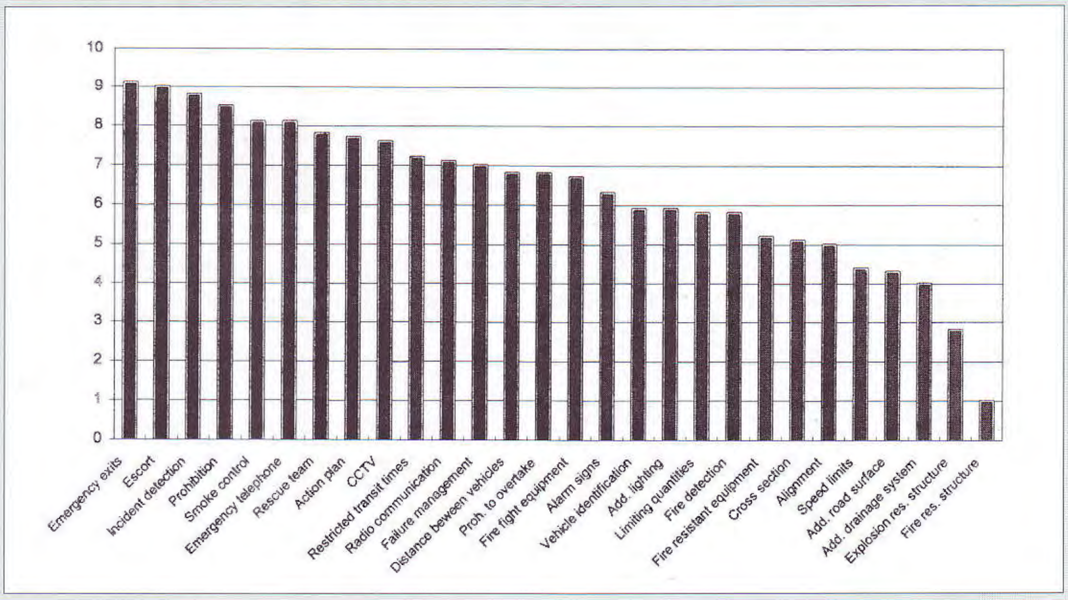


Table 3: Ranking of Measures by Their Effects on Reducing the Number of Victims

	High effect	Medium effect	Low effect
Low cost	Incident detection Prohibition	Restricted transit times Distance between vehicles overtaking prohibited Vehicle identification Addition of lighting Limiting quantities	Speed limits Road surface
Medium cost	Smoke control Emergency telephones Rescue team	Action plan CCTV Radio communication Failure management Fire fight equipment Alarm signs Fire detection Fire resistant equipment	Addition of drainage system Fire resistant structure
High cost	Emergency exits Escort		Cross section Alignment Explosion resistant structure

Intermediate Conclusions

The work of the joint OECD/PIARC Scientific Expert Group shows the increasing magnitude of the problem. Task 1 has, as assumed by the experts, proved that there is no consistency in the regulations of the transport of dangerous goods through tunnels at the international, national or regional level. It is surprising that the following four affected parties are not active and did not wish to participate in the project: the hauliers, producers and users of dangerous goods as well as the insurance companies. Although there are very few accidents with dangerous goods reported in tunnels, the potential risk is obvious and the effects are unforeseeable if something happens. This ambitious research project must overcome a number of difficulties:

1. This is an extremely complicated field with few experts.
2. The theoretical background in this field with a sound experimental basis is limited.
3. The existing database is poor.
4. Many partners are interested in this field but not all of them are active and supportive.
5. While many national administrations are aware of their responsibility and position towards society and have therefore contributed financially to the project

(e.g., Austria, Denmark, France, Japan, Netherlands, Norway, Spain, Sweden, Switzerland, UK, and the US), some other countries with tunnels that experience problems with the transport of dangerous goods are still not engaged financially or personally.

6. The scope of the research project covers the whole field from basic fundamental research to final application. This makes the work extremely difficult.
7. There are few, if any, road-related research projects in the OECD or in the European programs which are comparably demanding.
8. The subject covers many disciplines, including natural sciences, engineering, safety, environment, social sciences and policy.
9. It is not only one of the most ambitious projects at this moment, but also one of the most interesting as it can only be handled at the international level through close cooperation between the OECD and PIARC along with the outstanding experts from their Member countries.

The Expert Group is holding a special session on 4 October at the XXI World Road Congress in Kuala Lumpur. The discussion should prove to be of significant value to managers and operators of road networks internationally, and particularly for professionals from the Asia Pacific region in managing the rapid growth in demand for road infrastructure.

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A Study On The Use Oil Palm Fiber In Rubberized Stone Mastic Asphalt

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Abstract

Malaysia is a leading producer of oil palm in the world. As such, oil palm fiber is abundantly available in Malaysia. Although the oil palm fiber is used in several different areas a new usage of this material in Stone Mastic Asphalt mixes is worth investigating. This is because of the additional 20% cost to the mix using the traditional German Viatop66 fiber in the original specification of the SMA mix. This paper looks into the performance of SMA samples with Oil Palm fibers in comparison to SMA with the Viatop66.

1.0 Introduction

Most of the roads in Malaysia are paved with bitumen. Under the accelerated traffic growth and intense heat our pavements are subjected to drastic changes in their properties especially when heated in the presence of water and oxygen. When asphalt gets heated up, there is a tendency for the binder to soften and drain down slowly(1). A repetition of this process, may cause premature pavement distresses due to the accelerated loss of asphalt. The loss of asphalt is even higher in gap graded mixes like Stone Mastic Asphalt (SMA). One of the main reason for the addition of the fibers in SMA is to prevent the draining of the binder from the mix into the truck during transport of the material from the mixing plant to the construction site. The fibers also improve the service properties of the SMA mixes by forming a micromesh netting(2) in the asphalt mix to prevent drain-down of asphalt so as to increase the stability and durability of the pavement mix.

There are special fibers like Viatop66 fibers(3) which have been used in Stone Mastic Asphalt (SMA), for the last two decades. However, this product is currently been imported from Germany, which increases the cost of SMA in Malaysia by about 20%. In an effort to find an alternative but cost effective solution, oil palm fibers seems to offer an alternative additive for SMA fiber research. This is because oil palm fiber is found in abundance in Malaysia and the use of oil palm fiber in SMA can be inexpensive and may help reduce oil palm fiber waste in the country.

The main objective of this study is to analyze the performance of asphalt coated oil palm fiber in rubberized stone mastic asphalt. Several tests were conducted to determine the characteristics of oil palm fiber prior to use in stone mastic asphalt. This is to make sure that the organic contents in the oil palm fiber do not pose a problem in terms of durability of the mix.

2.0 Methodology

In this study, several experiments were conducted to determine the characteristics of oil palm and the control Arbocel Viatop66 fibers, in the rubberized binder. This was done to ensure that all the materials used fulfil the basic specifications and requirements of SMA(3). Samples were made with different sizes of oil palm fiber which approximately resemble the size of the imported Viatop66 fiber. The SMA with Viatop66 fiber was treated as the control sample.

Preliminary tests were carried out on the different types of raw oil palm fibers to determine their physical properties. The tests involved the analysis of fiber size, moisture content and specific gravity. For the long type fibers the tensile strength of the fiber was tested using the INSTRON Machine. Four sizes of oil palm fiber were selected and tested. The meshed fiber sizes of 106μm, 180μm, 250μm and 300μm were tested for the comparison study.

In addition to the above tests, the Resilient Modulus, Fatigue and Dynamic Creep tests were also conducted on the SMA mix with oil palm fiber and the control SMA with Arbocel Viatop66 fiber. The determination of the optimum content of oil palm fiber was done by the Marshall analysis and resilient modulus methods. The optimums were selected on basis of maximum stability, maximum bulk density, maximum resilient modulus and 4% airvoids.

The percentage of asphalt used was 6% by weight of total mix and the percentage of rubber in the asphalt-rubber blend was 4% by weight of asphalt. The meshed oil palm fibers and the Viatop66 fibers were tested for drain down properties using the German in-house 15W 40 motor oil-fiber test. The fibers were stirred at 1000 rpm in 160°C oil and is placed on a 500μm-sieve. After 5 minutes the mass of oil running through the sieve is measured.

Binder drain down tests were also carried out on the SMA samples with and without the fibers, to determine their binder retaining properties. The samples were prepared in accordance with Schellenberg's procedure(4). The aggregate gradation for SMA was based on the previous study carried in UPM(5).

3.0 Results

3.1 Physical Properties of Unmeshed Oil Palm Fiber

The tests show that the average tensile strength of the long type fiber strands is quite good (Table 1). This was used as the basis to select the type of oil palm fiber for meshing and grinding. From the above process four sizes were obtained. They are 106μm, 180μm, 250μm and 300μm. It was not possible to carry out tensile strength test on the short type fiber and fiber dust.

3.2 Oil Drain-down Properties of Meshed Fibers

Table 2 below shows the results of the oil retaining properties of the oil palm fiber against the imported Viatop66 fiber. The weight of oil drained out of the Viatop66 fibers is about 151.0g while the oil draindown value for the oil palm fiber is about 105.0g. The max allowable value for any suitable fibers is 180.0g.

Table 2: Oil Retaining Properties of Fibers

Specimen	Viatop66	Oil Palm Fiber
Weight of pan (g)	293.5	293.5
Weight of pan + Drained motor oil (g)	444.5	398.5
Weight of Motor Oil (g)	151.0	105.0

3.3 Results of Optimum Oil Palm Fiber Content

The resilient modulus test results at 25 ºC for 0%, 0.2%, 0.4%, 0.6%, 0.8% and 1.0% oil palm fiber content for each sizes are shown in Figure 1. The resilient modulus of SMA mix at 25ºC increased with an increase in percentage of oil palm fiber up to an optimum and then decreased. All of the fibers including the Viatop66 (control) displayed a similar increasing and decreasing trend. From the curves obtained, it can be seen that SMA samples with the oil palm fiber size of 300μm gave the highest resilient modulus value

Table 1: Physical Properties of Unmeshed Oil Palm Fibers

Fiber Category	Category	Length (mm)	Width (μm)	Moisture Content (%)		Specific Weight (kg/m³)	Tensile Strength (kPa)
				Air Dried	Saturated		
Dust	Minimum	3.0	27.77	13.4	32.5	–	–
Dust	Average	7.1	34.07	14.9	35.3	13.28	–
Dust	Maximum	13.0	38.89	16.9	36.9	–	–
Short	Minimum	7.0	127.78	12.9	40.1	–	–
Short	Average	17.4	151.48	13.3	42.0	8.74	–
Short	Maximum	28.0	161.11	13.6	44.2	–	–
Long	Minimum	20.0	105.58	5.7	61.5	–	–
Long	Average	142.3	358.34	7.0	63.2	7.73	5.67
Long	Maximum	315.0	777.77	7.7	65.2	–	–

and comparable with the control mix using Viatop66. The fiber content of about 0.6% gave the optimum modulus of about 3500MPa. The fiber size of 180µm however displayed the lowest value.

3.4 Binder Draindown

Binder drain down analysis was carried on SMA with Viatop66, SMA with oil palm fiber and SMA plain. Table 3 shows the results of the binder drain down tests. It was found that the mix with oil palm fiber showed a lower value compared to the mix without any fiber and the mix with the Viatop66 fiber. The maximum permissible value is 0.3 percent.

3.5 Marshall Stability

The Marshall Stability (Table 4) of the test samples and the respective graphs are shown in Figure 2. It can be seen that Marshall stability values increased when the percentage of oil palm fiber was increased. The highest stability values were obtained for 250µm fiber size with 16.31kN. A comparable result was obtained for the 300 micron fiber at 0.6% fiber content with stability about 12.37kN. However the stability values of each fiber content do not vary much between the four different sizes of oil palm fiber.

3.6 Marshall Density – Airvoids Analysis

Figure 3 to 5 show the Marshall bulk density, voids in the mix, flow and the Voids filled with Asphalt values. From the plots it can be seen that both the oil palm and Viatop66 fibers displayed similar trends. The oil palm fibers in particular showed values which are close to or even better than Viatop66 fibers. Table 5 shows the bulk densities for the optimum fiber contents of each fiber size.

Table 3: Binder Drain Down Properties of SMA

Mix Type	Sample No.	Wt. of Sample	Wt. Retained	% Retained	Ave. %
SMA-VT66	1	1016.4	1.20	0.1181	
	2	1018.1	1.21	0.1188	
	3	1017.0	1.20	0.1180	0.12
SMA-OPF	1	1019.0	1.00	0.0981	
	2	1018.6	0.90	0.0884	
	3	1016.9	1.10	0.1082	0.10
SMA-Plain	1	1019.5	4.59	0.4502	
	2	1017.1	2.54	0.2497	
	3	1019.7	3.57	0.3501	0.35

(note: binder content is 6.0%: VT66 = Viatop66: OPF = Oil Palm Fiber)

Table 4: Stability Results for Optimum Oil Palm Fiber Content

% OPT FIBER	STABILITY (KN)				
	106µm	180µm	250µm	300µm	Control
0.2	10.97	6.21	10.85	7.58	15.51
0.4	10.15	8.04	16.31	10.03	16.61
0.6	10.38	8.45	10.72	12.37	16.28
0.8	12.72	7.47	13.37	11.43	15.72
1	9.8	6.88	11.29	10.72	15

Table 5: Bulk Density of Each Oil Palm Fiber Size and Content

% FIBER	BULK DENSITY				
	106µm	180µm	250µm	300µm	Control
0.2	2.28	2.31	2.31	2.25	2.274
0.4	2.29	2.32	2.3	2.29	2.32
0.6	2.29	2.23	2.34	2.29	2.35
0.8	2.31	2.33	2.32	2.32	2.28
1	2.24	2.29	2.33	2.26	2.26

3.7 Dynamic Creep Performance

Dynamic creep test was carried out on SMA samples with Viatop66 and Oil palm fibers. A set of SMA samples without fibers were also tested for comparison purpose. Table 6 shows the results of the different SMA mixes. SMA with the Viatop66 fiber gave the highest values in terms of the number of load cycles to reach both the 1% and 3% strain levels. However SMA with the Oil palm fiber displayed equally good results.

Table 6: Dynamic Creep Results of SMA

Mix Type	1% Strain	3% Strain
SMA Plain	153	3906
SMA-VT66	454	7461
SMA-OPF	404	5400

4.0 Discussion and Conclusion

From the results obtained, it can be seen that the oil and binder retaining properties of the oil palm fiber are superior to the traditional Viatop66 fiber. The oil retaining value of the oil palm fiber (105.0g) is far below the max allowable maximum weight of 180.0g compared to 151.0g for the Viatop66 fiber. The binder draindown value of the SMA mix with oil palm fiber is very much lower than the permissible 0.3%. Both the oil and binder retaining values of the SMA mix with the oil palm fiber are more than acceptable. The results thus indicate that oil palm fiber may be used as a direct substitute for the more expensive cellulose-based fiber, currently used worldwide.

Table 7 shows the summary of SMA mix requirement(3) and the Marshall results of SMA with oil palm fiber (300 micron). Overall, SMA with oil palm fiber showed results which are within the SMA requirement range, except the flow which is a little lower than the required minimum.

The 300 micron fiber seems to be quite consistent interms of the overall performance (Table 8). It is obvious that the oil palm fiber performance in terms of stability, resilient modulus and bulk density is very much comparable to the Viatop66 fiber. For each oil palm size the optimum fiber content range was determined based on the maximum bulk density, stability and resilient modulus. The average fiber content ranges are shown in Table 9. For the chosen sizes the fiber content ranges from 0.53 to 0.73 percent which is a little higher than the normal average Viatop66 fiber content of 0.3 percent (from previous research).

Based on the above performance results, the oil palm fiber size of 300μm gave the overall best performance in terms of resilient modulus and stability and creep and met the requirements for NAPA SMA mix. The test results

Table 7: Comparison Between SMA with 0.6% Oil Fiber and SMA Control

Marshall Design Parameter	SMA-Oil Palm Fiber (size 300μm)	SMA Control (Viatop66 Fiber)	Acceptance Limits
Voids In Total Mix, VTM	4.64%	4.50%	3% – 5%
Asphalt Content, percent	6.0	6.10	6.0 min.
Voids In Mineral Aggregates, VMA	18.0	17	17% min.
Stability, N	12.37kN	16.28kN	6.2kN (min.)
Flow, 0.25mm (0.01 inch)	4.7	5.75	6 – 8
Compaction, number of blows at each side of test specimen	50	50	50

Table 8: Optimum Mix Properties

Size (μm)	Bulk Density	Stability (kN)	Resilient Modulus (MPa)
106	2.303	11.2	3220
180	2.313	8.2	2930
250	2.330	13.7	3175
300	2.306	12	3500
Control Viatop66	2.340	13.18	3963

Table 9: Optimum Percentage of Oil Palm Fiber

Size (µm)	for Bulk Density (%)	for Stability (%)	for Resilient Modulus (Mpa) (%)	Average, %
106	0.4 – 0.6	0.6 – 0.8	0.6 – 0.8	0.53 – 0.73
180	0.4 – 0.6	0.6 – 0.8	0.6 – 0.8	0.53 – 0.73
250	1	0.6	0.4 – 0.6	0.67 – 0.73
300	0.6 – 0.7	0.6 – 0.7	0.6	0.60 – 0.67

also show that the performance of SMA with oil palm fiber is quite comparable to SMA with the imported Viatop66 fiber in terms of dynamic load resistance. Eventhough the number of load cycles (5400) to reach the 3% strain for the oil palm fiber mix is slightly less than that of Viatop66 fiber (7461), it is certainly very much higher than the SMA mix without any fibers. This indicates that the oil palm fibers definitely improve the dynamic load resisting capability of the SMA mix compared to the one without any fibers.

It was also observed that nearly all the properties show a maximum when plotted against the different percentages of oil palm fiber. This could be due to the increased resistance to Marshall compaction of high fiber contents causing reduction in air voids. Thus quite a number of the properties were reduced at a higher airvoids.

The overall performance of oil palm fibers in SMA gives an indication that there is a very promising market for the use of oil palm fiber in road mix. Since the oil palm fibers are inexpensive the overall cost of the SMA mix could be almost comparable to the conventional mix. One of the major outcome of this research is the ability of the oil palm fibers in preventing the drain down of binders while improving the stability of the mix which should lead to improved field performance. In addition to that the chemical composition of the oil palm fibers show that they do not contain any deleterious elements that may cause serious problems when used in asphalt mixes. The low value of moisture content, and the alkali solubles in the oil palm fiber may assist resisting the higher heat temperatures of the asphalt.

Figure 1: Resilient Modulus Vs Percentage of Oil Palm Fiber

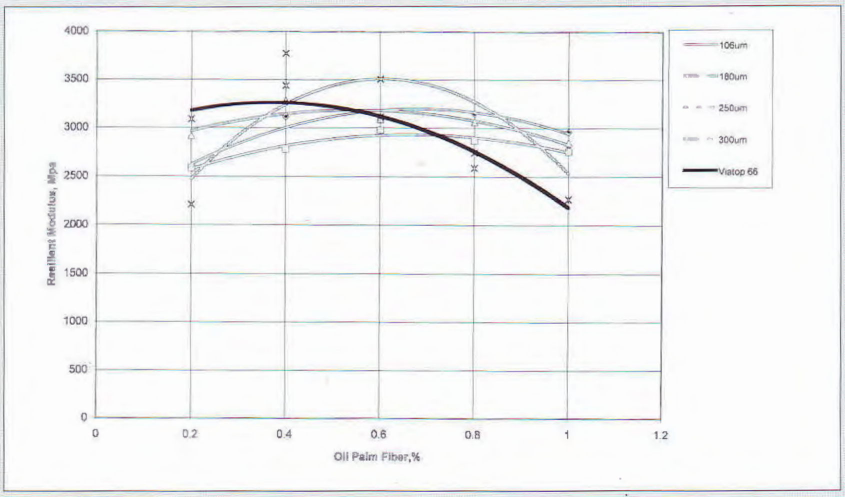


Figure 2: Marshall Stability Vs Percentage of Oil Palm Fiber

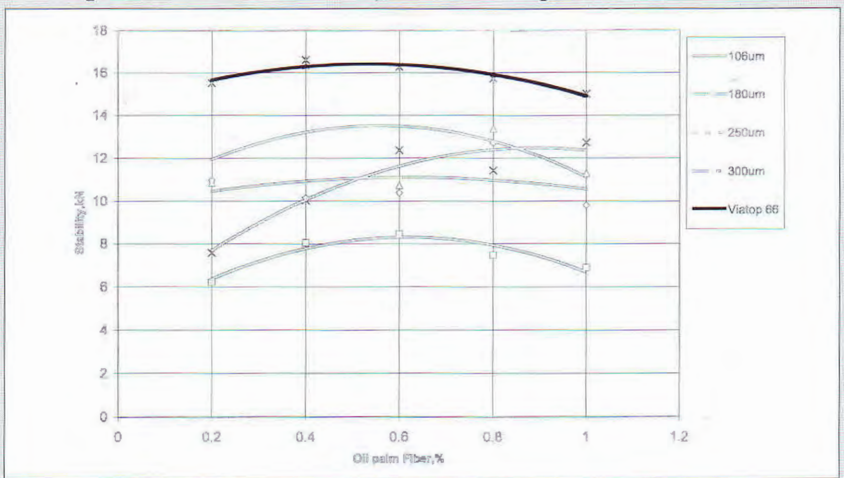


Figure 3: Bulk Density Vs Percentage of Oil Palm Fiber + A128

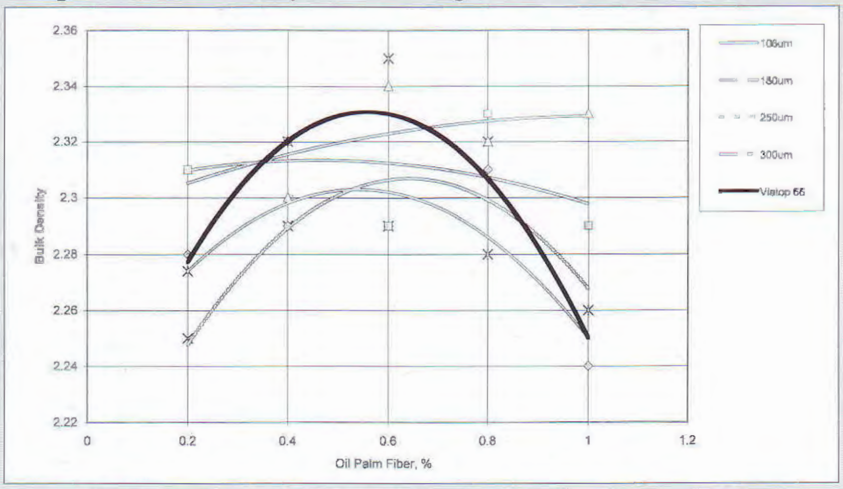


Figure 4: Flow Vs Percentage of Oil Palm Fiber + B168

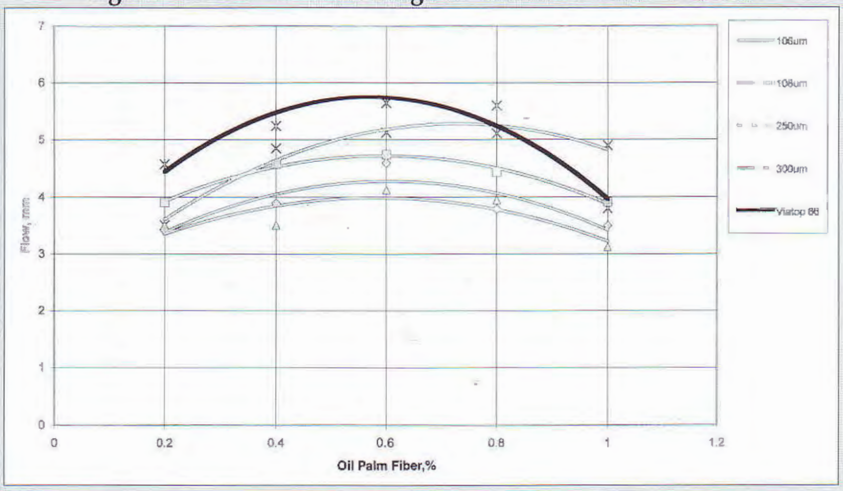
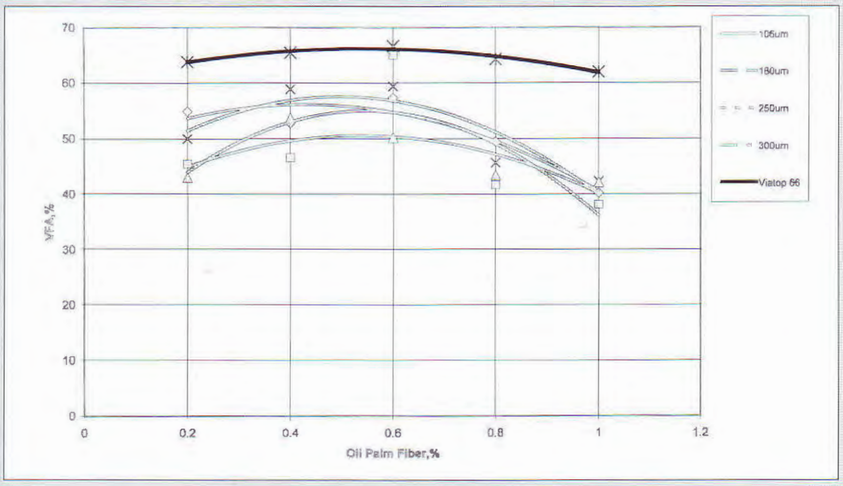


Figure 5: Voids Filled With Asphalt (VFA) Vs Percentage of Oil Palm Fiber



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